UNIVERSITI SAINS MALAYSIA

Second Semester Examination
2014/2015 Academic Session

June 2015

EBP 317/3 – Advanced Polymer Composites
[Komposit Polimer Termaju]

Duration : 3 hours
[Masa : 3 jam]

Please ensure that this examination paper contains TWELVE printed pages before you begin the examination.
[Sila pastikan bahawa kertas peperiksaan ini mengandungi DUA BELAS muka surat yang bercetak sebelum anda memulakan peperiksaan ini.]

This paper consists of SEVEN questions. TWO questions in PART A and FIVE questions in PART B.
[Kertas soalan ini mengandungi TUJUH soalan. DUA soalan di BAHAGIAN A dan LIMA soalan di BAHAGIAN B.]

Instruction: Answer **FIVE** questions. Answer **ALL** questions from PART A and **THREE** questions from PART B. If a candidate answers more than five questions only the first five questions answered in the answer script would be examined.
*[**Arahan**: Jawab **LIMA** soalan. Jawab **SEMUA** soalan dari BAHAGIAN A dan **TIGA** soalan dari BAHAGIAN B. Jika calon menjawab lebih daripada lima soalan hanya lima soalan pertama mengikut susunan dalam skrip jawapan akan diberi markah.]*

The answers to all questions must start on a new page.
[Mulakan jawapan anda untuk semua soalan pada muka surat yang baru.]

You may answer a question either in Bahasa Malaysia or in English.
[Anda dibenarkan menjawab soalan sama ada dalam Bahasa Malaysia atau Bahasa Inggeris.]

In the event of any discrepancies in the examination questions, the English version shall be used.
[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah digunapakai.]

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PART A / *BAHAGIAN A*

1. [a] What is a composite material? State three criteria that need to be satisfied before a material can be called a composite.

Apakah bahan komposit? Nyatakan tiga kriteria yang perlu dipenuhi agar sesuatu bahan boleh dikatakan komposit.

(25 marks/*markah*)

[b] Derive the following expression:

Terbitkan persamaan berikut:

$$\rho_c = \frac{1}{(w_f \rho_f) + (1 - w_f)\rho_m}$$

where w and ρ are the weight fractions and density. The subcripts c, f and m refer to composite, fiber and matrix, respectively.

di mana w dan ρ adalah pecahan bagi berat dan ketumpatan. 'Subscripts' c, f dan m masing-masing merujuk kepada komposit, gentian dan matrik.

(25 marks/*markah*)

[c] Figure 1 shows a schematic diagram of one process used in the manufacturing of composites. Describe the process and give an example of component or product that can be produced via this manufacturing technique.

Rajah 1 menunjukkan diagram skematik suatu proses yang digunakan bagi pembuatan komposit. Huraikan proses tersebut dan berikan satu contoh komponen atau produk yang boleh dihasilkan melalui teknik pembuatan ini.

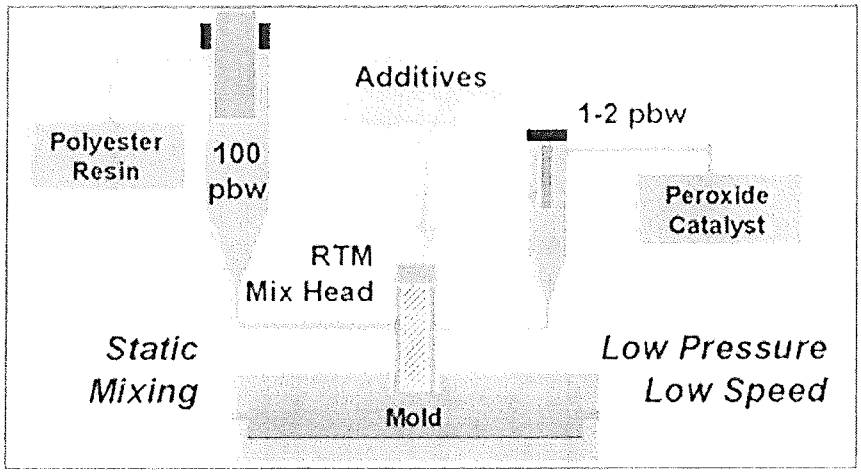


Figure 1 - Schematic diagram of a process used in the manufacturing of composites

Rajah 1 - Diagram skematik proses yang digunakan bagi pembuatan komposit

(50 marks/*markah*)

2. [a] Rule of mixture and Halpin-Tsai equations are two theories that are frequently used in predicting the mechanical properties of composites. Write a critical essay on the strength and weakness of both theories.

Hukum campuran dan persamaan Halpin-Tsai merupakan dua teori yang biasa digunakan untuk meramalkan sifat mekanik komposit. Tuliskan satu karangan kritik tentang kekuatan dan kelemahan kedua-dua teori tersebut.

(50 marks/*markah*)

[b] Energy absorbing mechanisms play a crucial role in determining the toughness of a polymer composite. Describe clearly the types of energy absorbing mechanisms and what are the techniques normally used in elucidating the occurrence of these mechanisms.

Mekanisme penyerapan tenaga memainkan peranan yang penting dalam menentukan keliatan suatu komposit polimer. Terangkan dengan jelas bentuk mekanisme penyerapan tenaga dan apakah teknik yang biasa digunakan untuk membuktikan kewujudan mekanisme tersebut.

(50 marks/*markah*)

PART B / *BAHAGIAN B*

3. [a] Describe the production of carbon fibers. Relevant illustrations must be provided.

Jelaskan penghasilan gentian karbon. Lakaran-lakaran yang berkaitan perlu diberikan.

(50 marks/*markah*)

[b] The interfacial bonding strength between carbon fibers and epoxy resin can be improved via surface modification of carbon fibers with aqueous ammonia for different lengths of time (24, 48, 72, 96 and 120 h). Figure 2 shows the surface topologies of carbon fibers before and after treatment as observed via Atomic Force Microscopy (AFM). The values of surface roughness (Ra) are given in Table 1. Discuss the effect of the treatment on the fiber surface and the possible bonding mechanism that might occur between carbon fibers and epoxy resin.

Kekuatan ikatan antaramuka di antara gentian karbon dan resin epoksi boleh dipertingkatkan melalui modifikasi permukaan gentian karbon menggunakan akueus ammonia untuk tempoh masa yang berbeza (24, 48, 72, 96 dan 120 h). Rajah 2 menunjukkan topologi permukaan gentian karbon sebelum dan selepas rawatan seperti yang diperhatikan melalui 'Atomic Force Microscopy' (AFM). Nilai bagi kekasaran permukaan (Ra) diberikan dalam Jadual 1. Bincangkan kesan rawatan terhadap permukaan gentian dan mekanisme ikatan yang mungkin wujud di antara gentian karbon dan resin epoksi.

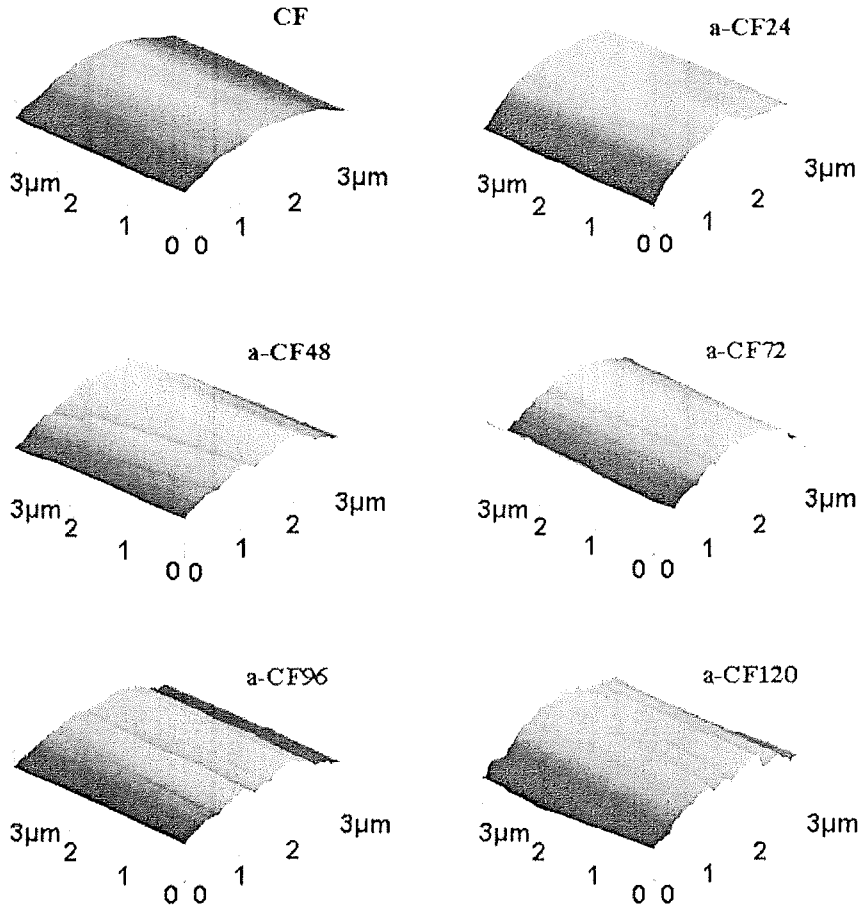


Figure 2 - Three dimensional AFM images of the surfaces of untreated (CF) and treated carbon fibers (a-CF) for different lengths of time.

Rajah 2 - Gambaran AFM tiga dimensi bagi permukaan gentian tidak dirawat (CF) dan dirawat (a-CF) untuk tempoh masa yang berbeza.

Table 1 - Surface roughness (Ra) of untreated and treated carbon fibers.

Jadual 1 - Kekasaran permukaan (Ra) bagi gentian karbon tak dirawat dan dirawat.

Sample	CF	a-CF24	a-CF48	a-CF72	a-CF96	a-CF120
Ra (nm)	12.5	19.2	25.2	32.1	42.3	57.4

(50 marks/*markah*)

4. [a] Describe the concept of load transfer.

Jelaskan konsep pemindahan beban.

(20 marks/*markah*)

[b] Single-fiber experiments are used to obtain quantitative information about the strength of interfacial bonding. Figure 3 shows a test setup of a single-fiber experiment. Name the experiment and explain in details this experiment. Schematic stress distributions and load-displacement plot must be included.

Ujian gentian tunggal digunakan untuk mendapatkan maklumat kuantitatif berkaitan kekuatan ikatan antaramuka. Rajah 3 menunjukkan persediaan ujian gentian tunggal. Namakan ujian tersebut dan jelaskan secara terperinci ujian ini. Skema taburan tegasan dan plot beban-anjakan mesti disertakan.

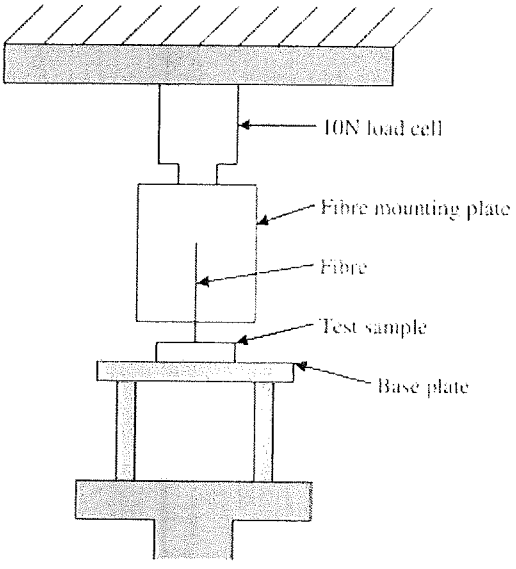


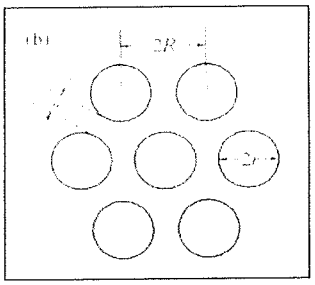
Figure 3 - A test setup of a single-fiber experiment

Rajah 3 - Persediaan bagi suatu ujian gentian tunggal

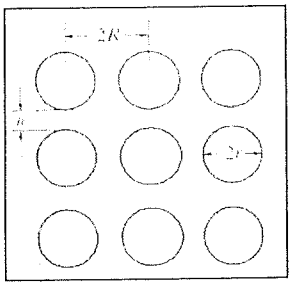
(50 marks/*markah*)

[c] Prove that for hexagonal and square packing arrangements, fiber volume fractions are given as:

Buktikan bagi penyusunan heksagonal dan segi empat sama, pecahan isipadu gentian diungkapkan sebagai:



$$V_f = \left(\frac{\pi}{2\sqrt{3}}\right)\left(\frac{r}{R}\right)^2$$



$$V_f = \left(\frac{\pi}{4}\right)\left(\frac{r}{R}\right)^2$$

Determine the maximum fiber volume fractions for both arrangements.

Tentukan pecahan isipadu gentian maksima bagi kedua-dua penyusunan.

(30 marks/*markah*)

5. [a] Write a shot note on ultrasonic testing and representation of data.

Tuliskan nota pendek tentang ujian utrasonik dan perwakilan data.

(50 marks/*markah*)

[b] The following data were obtained in a resin burn-off test of an E-glass-polyester sample:

Data yang berikut diperolehi dari ujian bakar habis matrik yang melibatkan sampel gentian kaca-E-poliester:

Weight of an empty crucible = 10.1528 g
Berat bekas kosong = 10.1528 g

Weight of crucible + sample before burn-off = 10.5219 g
Berat bekas + sampel sebelum bakar habis = 10.5219 g

Weight of crucible + sample after burn-off = 10.3221 g
Berat bekas + sampel selepas bakar habis = 10.3221 g

Calculate the fiber weight fraction, the fiber volume fraction and the density of the composite sample. Given: fiber density = 2.54 g/cm^3 and matrix density = 1.25 g/cm^3.

Kirakan pecahan berat gentian, pecahan isipadu gentian dan ketumpatan komposit. Diberi: ketumpatan gentian = 2.54 g/cm^3 dan ketumpatan matrik = 1.35 g/cm^3.

(30 marks/*markah*)

[c] State 4 main purposes of sizing during the manufacture of glass fibers.

Nyatakan 4 tujuan utama 'sizing' semasa pembuatan gentian kaca.

(20 marks/*markah*)

6. Write short notes on the following topics:

Tuliskan nota-nota ringkas bagi tajuk-tajuk yang berikut:

[a] Fiber flexibility

Kelenturan gentian

(30 marks/*markah*)

[b] Vacuum bagging

Beg vakum

(40 marks/*markah*)

[c] Pultrusion

Pultrusi

(30 marks/*markah*)

7. [a] Short carbon fiber reinforced polyamide 66 (PA66) in the form of a plate with dimensions of 120 mm x 120 mm x 3 mm was produced using injection moulding technique. Dumbell shaped specimens were cut parallel to the mould filling direction. Tensile test was conducted until the composite specimen failed. Use the information given to determine:

(i) tensile modulus of the composite

(ii) transition from matrix controlled fracture to fiber controlled fracture occur

(iii) full fiber controlled fracture takes place

(iv) tensile strength of the composite

(v) tensile strength of the composite if 80% of the fiber is aligned parallel to the mould filling direction.

Please state clearly any assumption made.

Satu plat komposit poliamida 6.6 (PA66) yang diperkuatkan gentian karbon pendek berukuran 120 mm x 120 mm x 3 mm telah dihasilkan menggunakan teknik pengacuanan suntikan. Sampel berbentuk dumbel telah dipotong dalam arah selari dengan arah pengisian acuan. Ujian tensil telah dijalankan sehingga spesimen komposit gagal. Berdasarkan maklumat yang diberi tentukan nilai:

(i) modulus tegangan komposit

(ii) berlakunya peralihan daripada kegagalan terkawal matrik kepada kegagalan terkawal gentian

(iii) berlakunya kegagalan terkawal gentian sepenuhnya

(iv) kekuatan tegangan komposit

(v) kekuatan tegangan komposit sekiranya 80% daripada gentian terjajar selari dengan arah pengisian acuan.

Sila nyatakan dengan jelas sebarang anggapan yang dibuat.

(80 marks/*markah*)

[b] What would you expect to happen to the stiffness and strength properties of the PA66 composites if:

(i) the specimens were cut perpendicular to the mould filling direction.

(ii) the short carbon fiber is replaced with milled carbon fiber.

Apakah yang anda jangkakan akan terjadi kepada sifat kekakuan dan kekuatan komposit PA66 tersebut sekiranya:

(i) sampel dumbel dipotong dalam arah bertegak lurus dengan arah pengisian acuan.

(ii) gentian karbon pendek digantikan dengan "milled carbon fiber".

(20 marks/*markah*)

Given / *Diberi:*

Ratio of density of constituent materials	= 1.67
Nisbah ketumpatan bahan juzuk	*= 1.67*
Weight fraction of PA66	= 0.7
Pecahan berat PA66	*= 0.7*
Radius of carbon fiber	= 3 micron
Jejari gentian karbon	*= 3 mikron*
Aspect ratio of carbon fiber	= 66.7
Nisbah aspek gentian karbon	*= 66.7*
Density of PA66	= 1.14 g/cm^3
Ketumpatan PA66	*= 1.14 g/cm^3*
Ratio of tensile modulus of constituent materials	= 85.2
Nisbah modulus tegangan bahan juzuk	*= 85.2*

Poisson's ratio of PA66 *Nisbah poisson PA66*	= 0.33 *= 0.33*
Poisson's ratio of carbon fiber *Nisbah poisson gentian karbon*	= 0.25 *= 0.25*
Shear modulus of PA66 *Modulus ricih PA66*	= 1.02 GPa *= 1.02 GPa*
Interfacial shear strength *Kekuatan ricih pada antaramuka*	= 32 MPa *= 32 MPa*
Fibre orientation correction factor *Faktor pembetulan orientasi gentian*	= 0.38 *= 0.38*
Fibre length correction factor *Faktor pembetulan panjang gentian*	= 0.87 *= 0.87*
Ratio of tensile strength of constituent materials *Nisbah kekuatan tegangan bahan juzuk*	= 45.7 *= 45.7*
Tensile strength of carbon fiber *Kekuatan tegangan gentian karbon*	= 3.2 GPa *= 3.2 GPa*
Critical volume fraction of fiber in continuous fibre composites *Pecahan isipadu kritik gentian dalam komposit gentian selanjar*	= 0.03 *= 0.03*

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